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Title: Air Blast Meshing & Pressure Mapping

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Air Blast Meshing & Pressure Mapping

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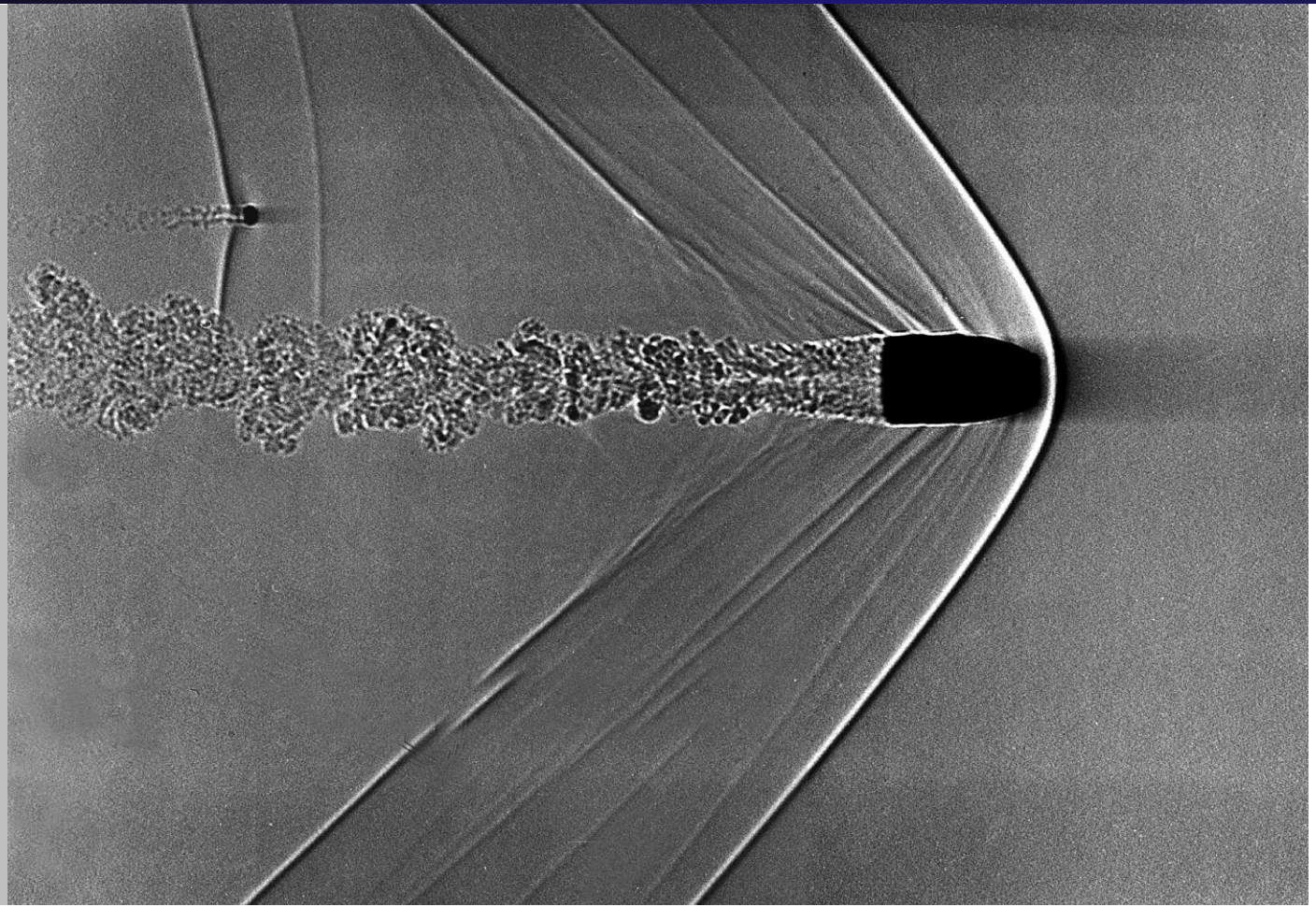
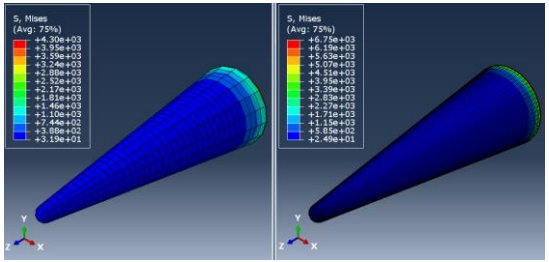


Fig. 1.

Shadowgraph captures a bullet traveling at 1.5 times the speed of sound. A pressure wave is depicted at the fore, and turbulence at the rear

Project Goals

- Mesh sensitivity study
  - Determine at what mesh density results converge
  - Build a model that reflects theoretical solutions



- Map experimental pressure data onto the surface of the cone
  - Track rigid body motion

- Stresses in conic Body
  - Observe how the model reacts to stresses different than the ones tested in the mesh sensitivity study

Mesh Sensitivity

Cantilever Beam Example

- Euler-Bernoulli beam theory
- Measured deflections

Assumptions:

– Plane sections remain planar

– Deformed angles are small

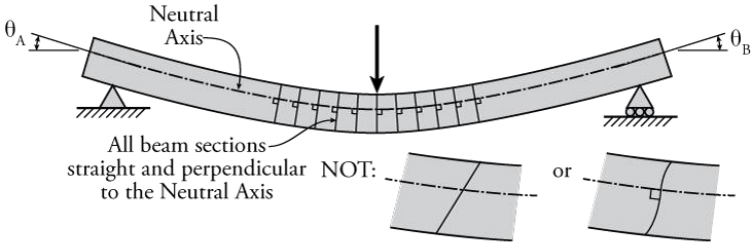
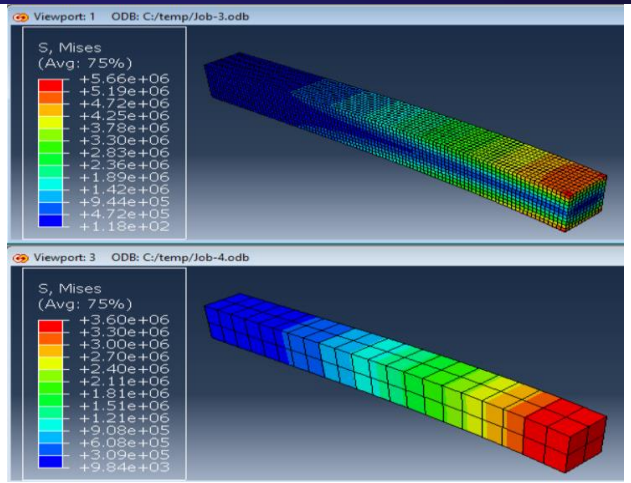


Fig. 2.



Deflection Equation

$$w(x) = \frac{qx^2(6L^2 - 4Lx + x^2)}{24EI}$$

q = distributed load

L = length

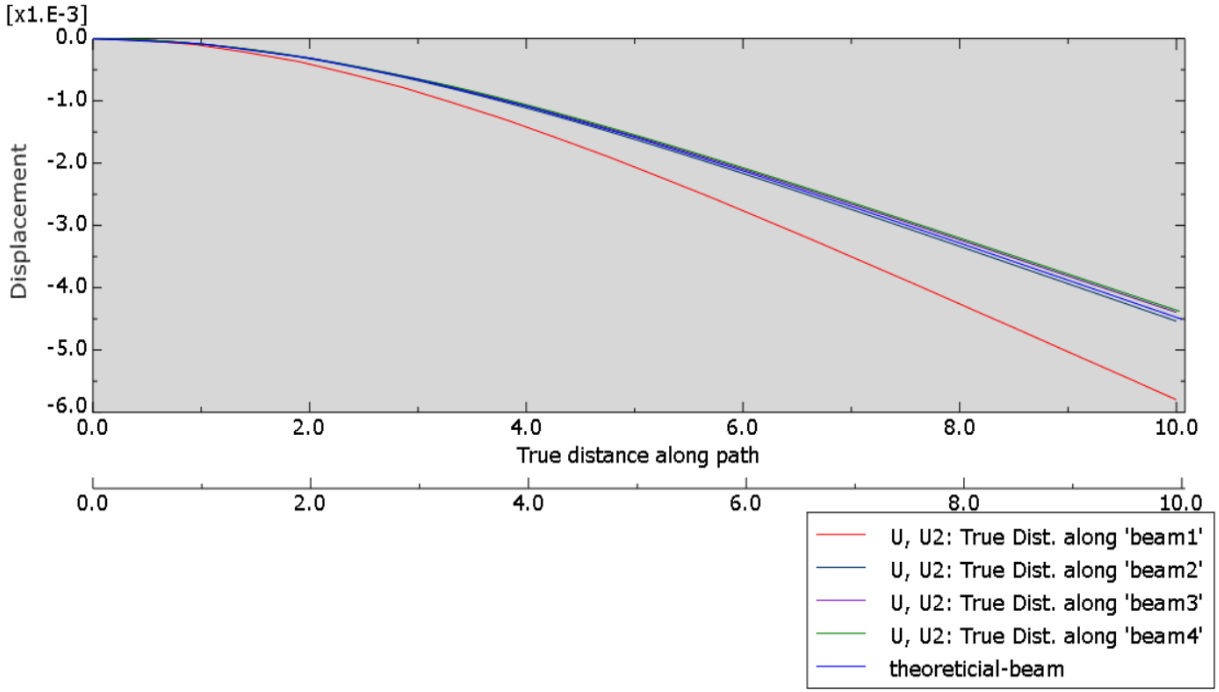
I = second moment of area

Beam Theory Results

- Good correlation and signs of convergence

% Error calculated at maximum displacement:

- ≈ 80 elements 33.17%
- ≈ 1,200 elements 4.19%
- ≈ 13,000 elements 0.82%
- ≈ 34,000 elements 0.53%

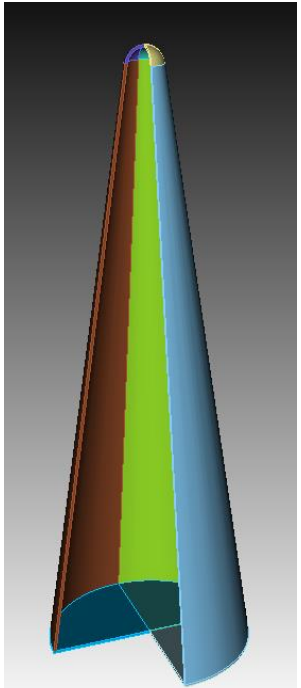


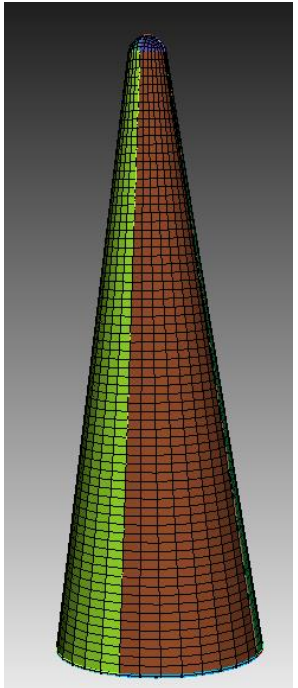
Building the Model

- Engineering Drawings
  - Simplifications
  - 0.25 in. thickness
- CUBIT python command line

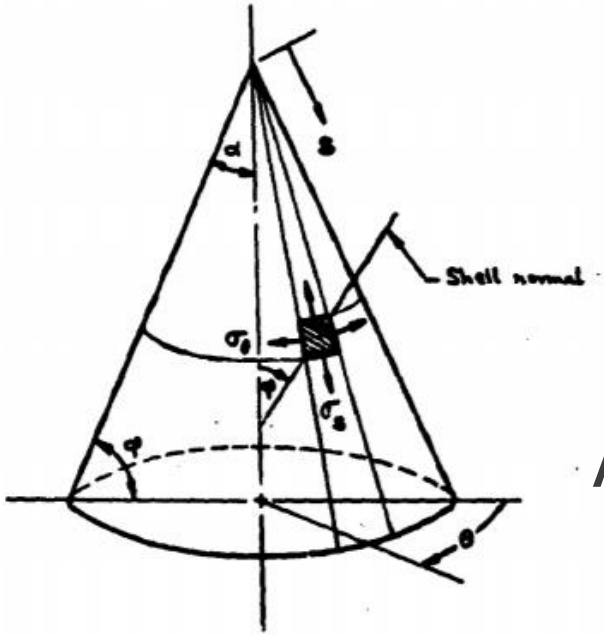
```
Command Line
%>
%>cubit.cmd('#Closure Plate ')
%>cubit.cmd('create Cylinder height 0.25 radius  10.191176')
Successfully created cylinder volume 4
Journaled Command: create cylinder height 0.25 radius 10.191176

%>cubit.cmd('move Volume 4  z -39.681')
 Moved Body 4:  x 0.000000e+00  y 0.000000e+00  z -3.968100e+01
Journaled Command: move volume 4 z -39.681

%>cubit.cmd('imprint volume all ')
Preserving undo information...done
Group imprint finished.
Updated volume(s): 1, 3, 4
IMPRINT completed.
cubit.cmd(" Enter cubit command
Script | Command | Error | History
```

- Model built and meshed in CUBIT





Theoretical Solutions



Hoop Stress:

$$\sigma_\theta = \frac{ps}{h}\tan(\alpha)$$

Meridional Stress:

$$\sigma_s = \frac{ps}{2h}\tan(\alpha)$$

Radial Displacement:

$$u_r = \frac{ps^2 \sin(\alpha)\tan(\alpha)}{2Eh}(2 - v)$$

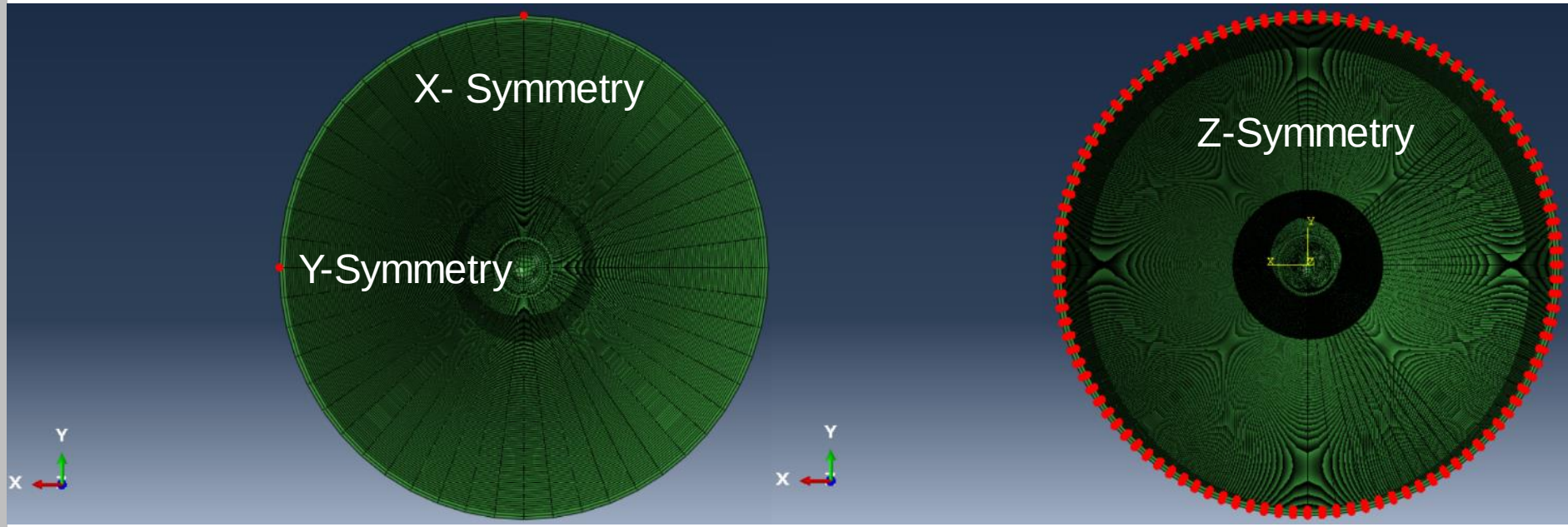
Assumptions:

- Thin Shell (h/a ≤ 1/15) → (0.03 ≤ 0.067)
- Perfectly elastic, homogeneous, and isotropic solid
- Only loading is internal pressure
- Uniform thickness

Model Setup

Boundary Conditions:

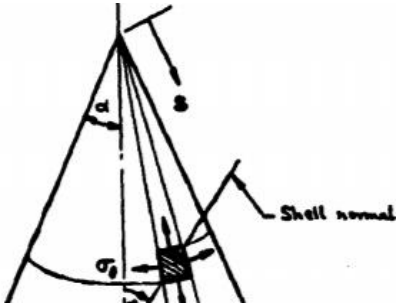
- Highlighted nodes are fixed with the listed conditions

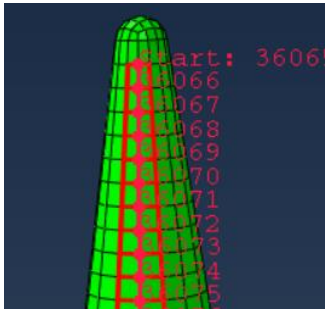


Model Setup

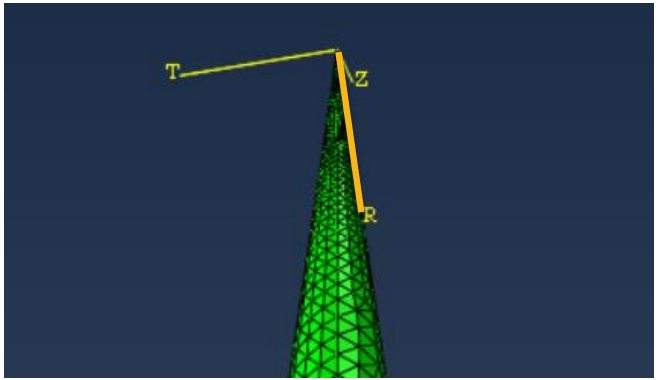
Path Definition:

"s = distance of a point of the middle surface from the vertex measured along a generator."

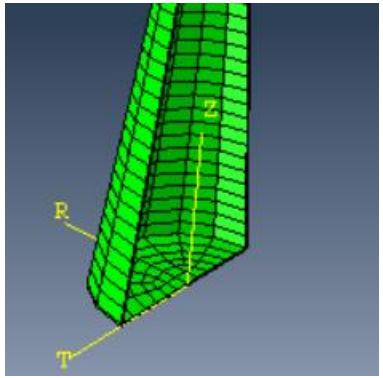




Coordinate Systems:



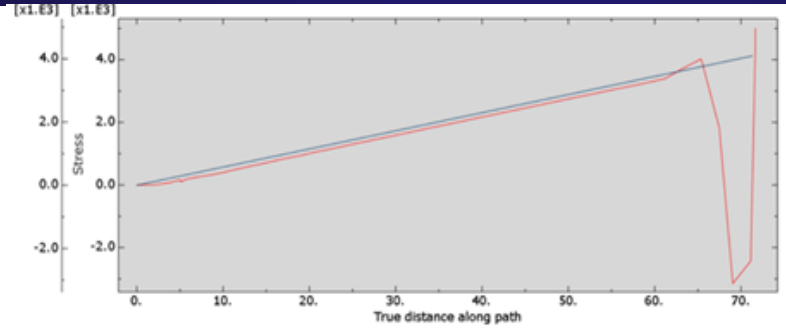
- Meridional Stress (S11 tensor)



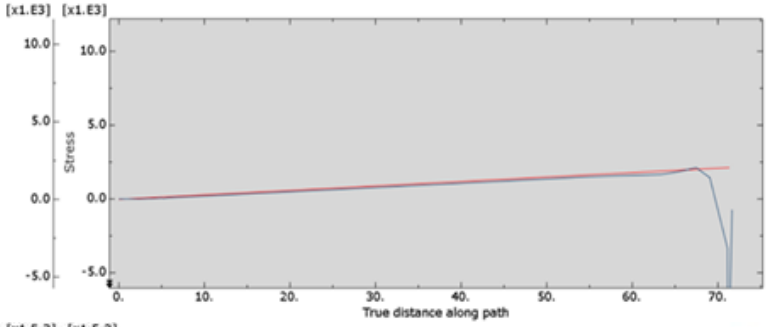
- Hoop Stress (S22 tensor)
- Radial Displacement (U1 component)

Regular Cone Comparison (3D model)

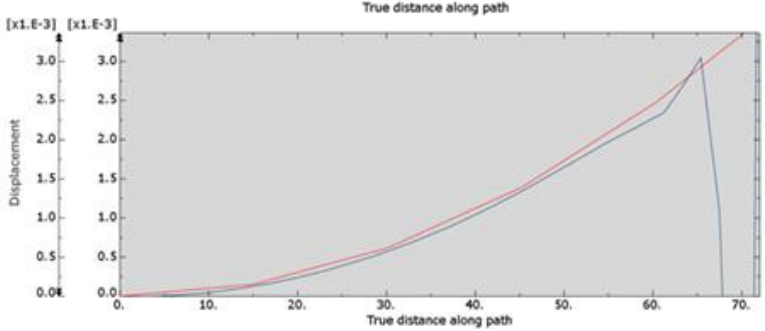
Hoop Stress
4.85%

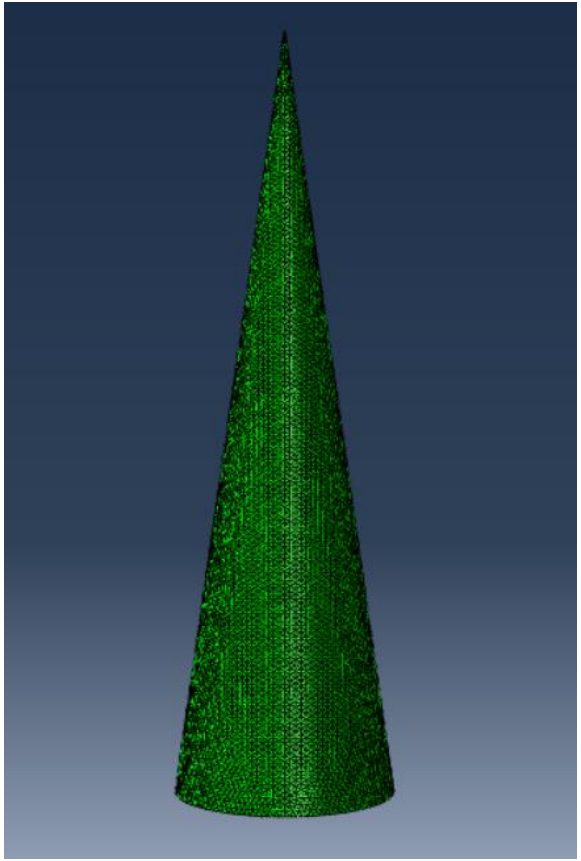


Meridional Stress
6.20%



Radial Displacement
3.95%





False Starts

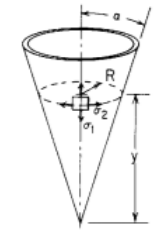
- **Inertia Relief**

  Boundary conditions led to asymmetry and stress concentrations

- **Base Plate**

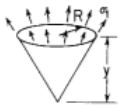
  Initially an aft base plate was excluded

2. Cone



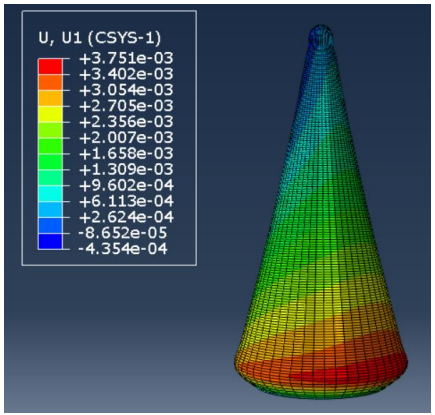
$\frac{R_2}{t} > 10$

2a. Uniform internal or external pressure, q force/unit area; tangential edge support

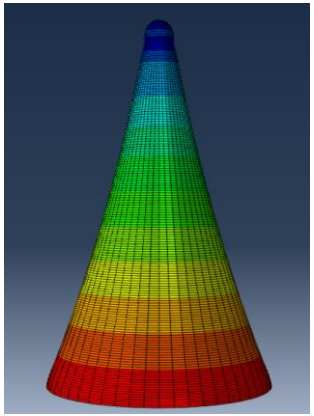


$$\sigma_1 = \frac{qR}{2t\cos\alpha}$$
$$\sigma_2 = \frac{qR}{t\cos\alpha}$$
$$\Delta R = \frac{qR^2}{Et\cos\alpha}\left(1 - \frac{\nu}{2}\right)$$
$$\Delta y = \frac{qR^2}{4Et\sin\alpha}(1 - 2\nu - 3\tan^2\alpha)$$
$$\psi = \frac{3qR\tan\alpha}{2Et\cos\alpha}$$

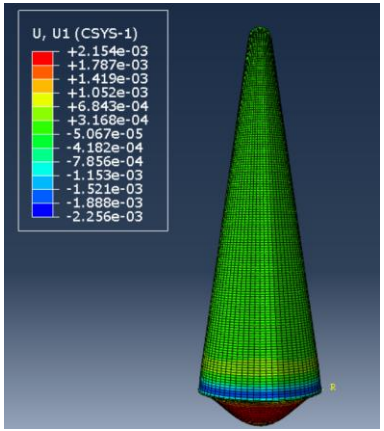
Initial BC's



Inertia Relief

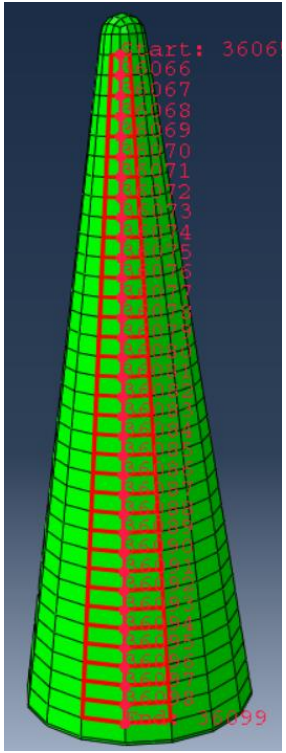


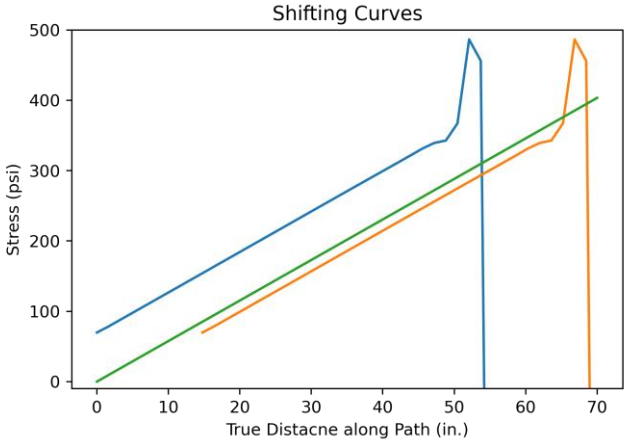
Base Plate



False Starts

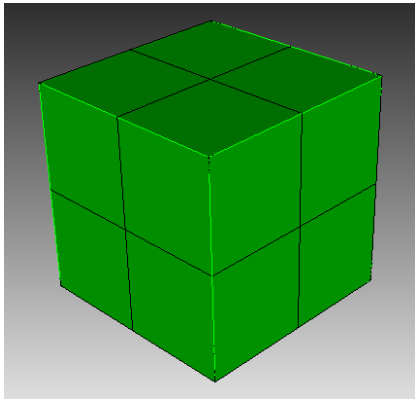
- **Shifting Data**



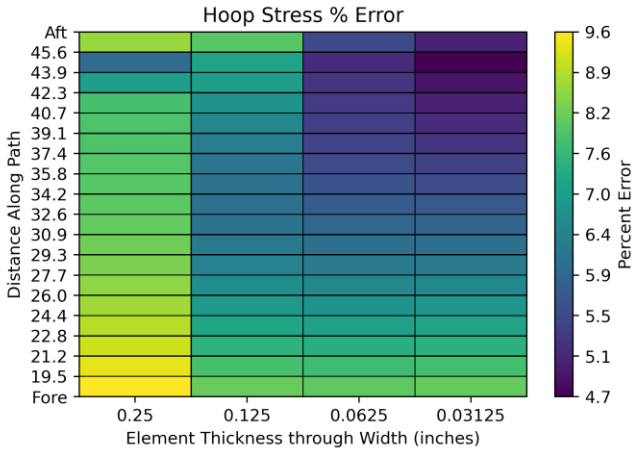


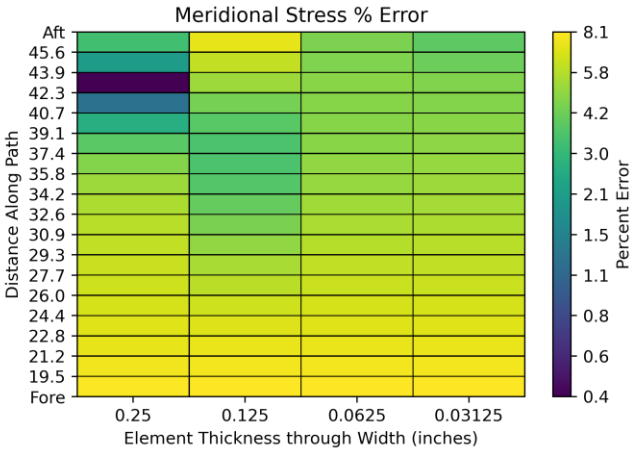
- **Mesh Refinement**

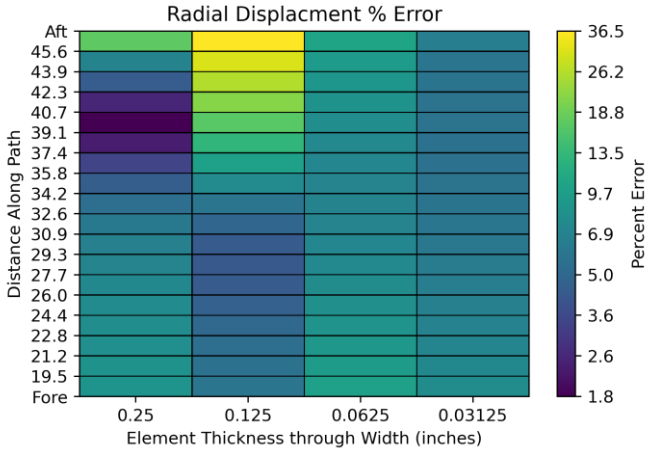
  Each element cut into 8 using CUBIT



Mesh Sensitivity Results





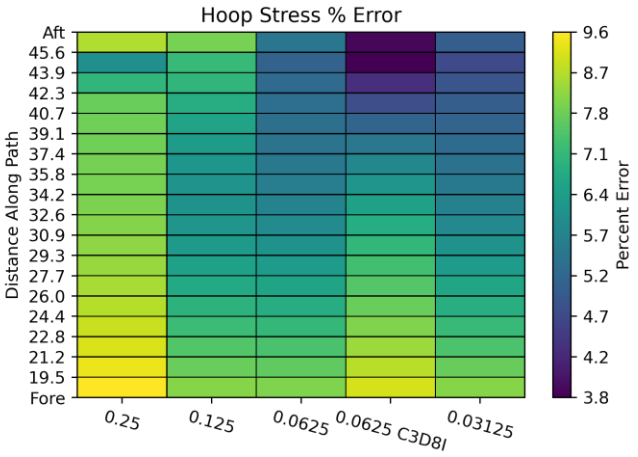


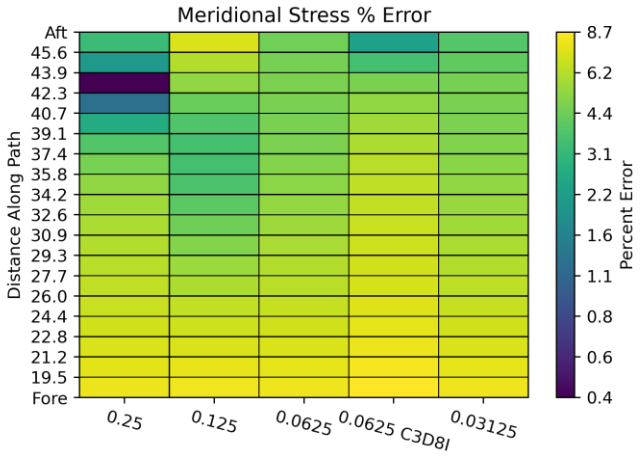
Hoop: 8.23, 6.84, 6.14, 6.03

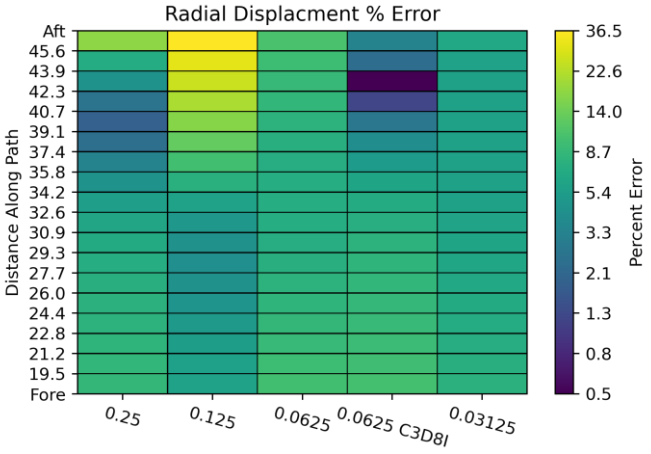
Meridional: 5.01, 5.48, 5.77, 5.74

Displacement: 6.47, 11.75, 8.24, 6.28

Other Element types





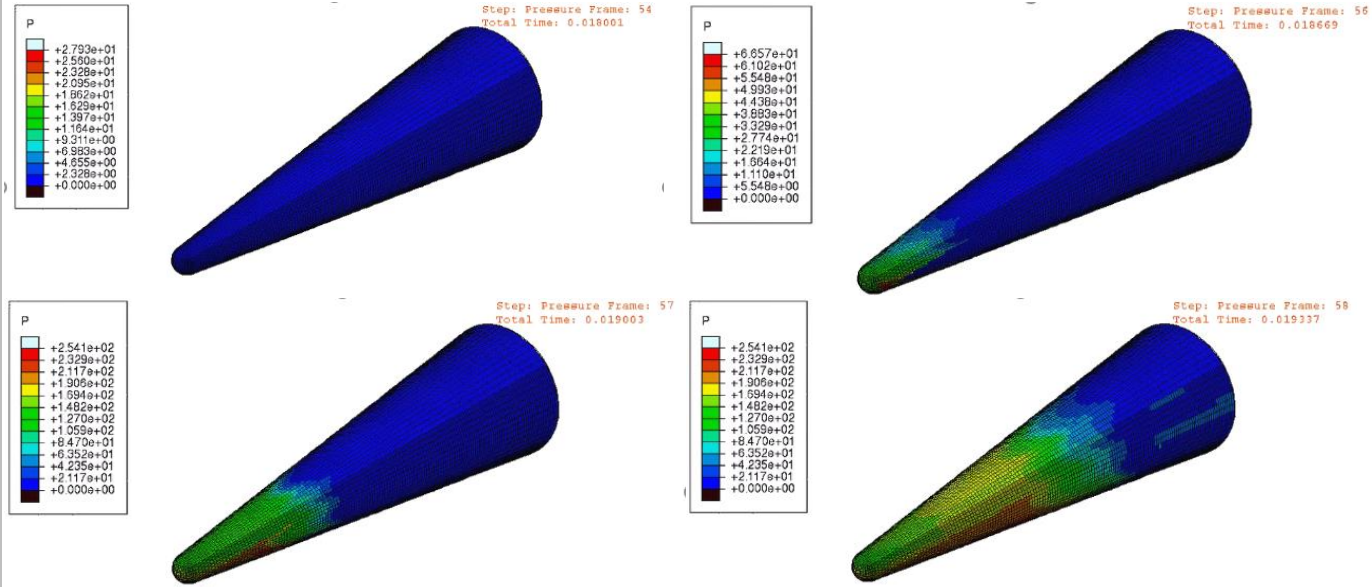


- C3D8I elements are supposed to have better performance with bending problems

Pressure Mapping

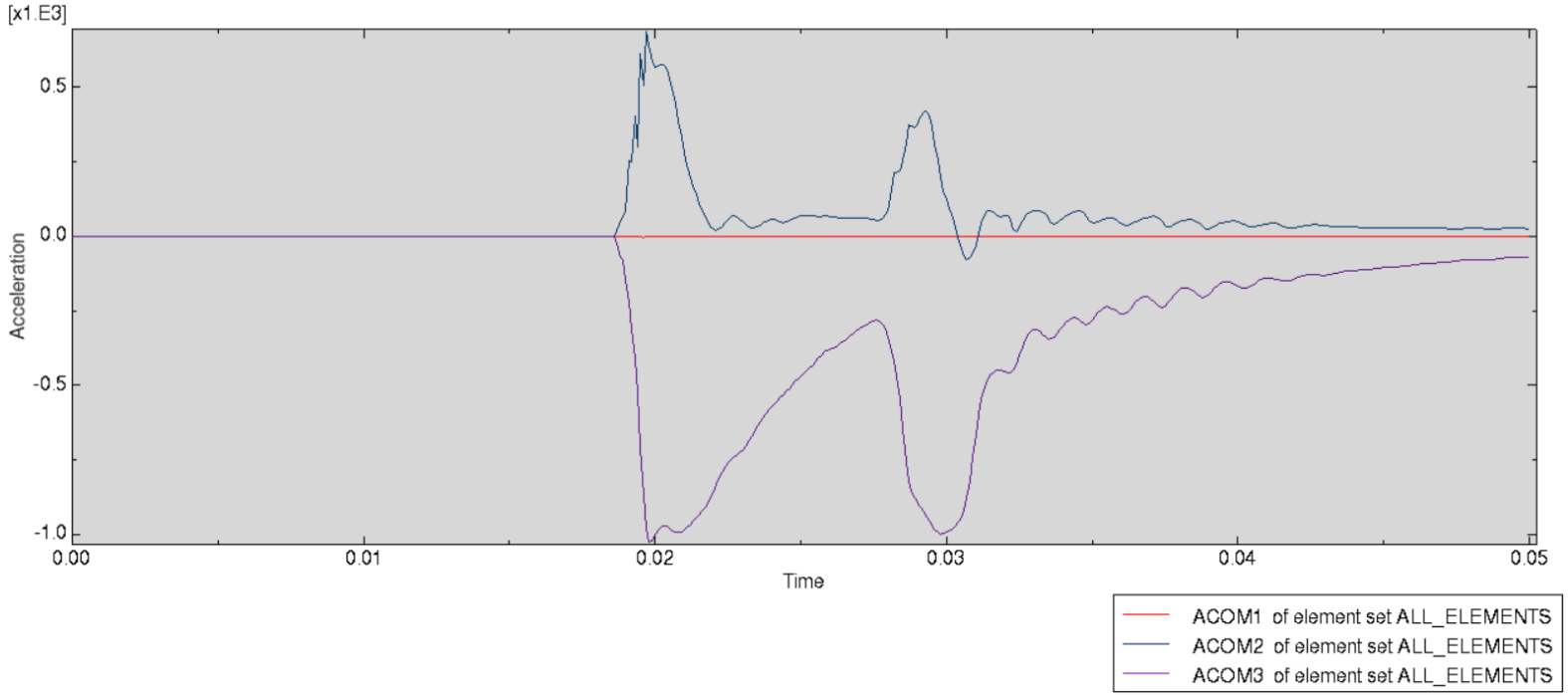
- Suite of scripts for pressure mapping
  - provided by Paula Rutherford

- Time dependent pressure loading



Pressure Mapping Results

Rigid Body Motion



Next Steps

- **Python pressure mapping**
  - Build mapping script using nearest neighbor interpolation
  - Compare nearest neighbor with linear interpolation.

- **Analyze stresses induced by the pressure load**
  - As pressure increases how do stresses change with
    - Environment
    - Geometry
    - Material properties

Works Cited

Fig. 1. https://www.nasa.gov/mission_pages/galex/20070815/f.html

Fig. 2. https://learnaboutstructures.com/Bernoulli-Euler-Beam-Theory